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MAGNETOELASTIC RESPONSE AND DOMAIN WALL BEHAVIOR OF TWO 5% CHROMIUM HEAT-TREATED TOOL STEEL TORQUE TRANSDUCERS

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We have produced torque sensors from type A-2 and type H-13 tool steels for industrial torque transfer applications in a 0.75 inch outer diameter hollow shaft by magnetically polarizing two adjacent sections of the shaft with oppositely directed circumferential magnetization. The resultant field signal, found to be linear with applied torque up to 15 N-m, emanated from the domain wall formed between the two regions and was easily detected with a Gaussmeter. A two-step heat treatment, consisting of a rapid quench from a temperature higher than the Curie temperature of the ferromagnetic steel in order to erase magnetic history, followed by a slow cool from a lower temperature to restore desired magnetic and mechanical properties, was then applied to the samples. This resulted in an increase in torque-load sensitivity (field signal in μG per unit applied shear stress in lb/in^2 or psi) from 48.2 μG/psi to 59.2 μG/psi in the A-2 sample and from 125 μG/psi to 189 μG/psi in the H-13 sample, as well as remarkably improved linearity of the signals and a more reliable re-zeroing of the sensors following removal of the applied torque. Simultaneously, the magnetic hysteresis properties of the samples were studied prior and subsequent to the heat treatments. The axial coercive forces were found to decrease in each case, with the percent of decrease in excellent correlation to the percent of increase in the sensitivities found above, while the circumferential coercive forces were sufficiently large to guarantee integrity of the magnetically polarized regions comprising the sensor. The width and magnetic intensity of the domain wall in each sensor were also measured using the technique of magnetic force microscopy (MFM).